Narrative

Nationally, public service agencies are clamoring for fixed and mobile broad band data access. This access must be secure and dependable as lives will depend on its reliability.

During the Hayman Fire of 2002, communications presented the largest obstacle to overcome for all emergency service agencies involved with suppression and community protection. These obstacles were common everyday problems that became major impediments to the publics' safety as well as the safety of the fire and law enforcement officers in the field. In many situations, field command personnel could only receive limited 800MHz radio traffic. Many firefighters faced life threatening situations due to the lack of communication capability.

In fact, the Lake George and Douglas County Emergency Operations Centers had to depend on exchange of information via human transport between the two Centers until satellite phones were set up, giving voice capability.

Recently, the Denver Police Department setup a wireless video surveillance, only to find that they received the signal from a neighbor that setup a personal wireless surveillance on his new car. This represents a typical congestion issue with public wireless frequencies.

Everyday, fire and ambulance service personnel in some parts of the country including Colorado have no data capability in the field. There is absolutely no transmission of patient data to hospital emergency room personnel at this time, firefighters have zero access to databases on agency servers when they are on an incident and law enforcement personnel are subject to the limitations of the public system that they are currently using to transmit NCIC data.

All of these issues present a critical lack of safety for both the emergency service personnel and the public that they serve.

With today's security environment and the ongoing threat potential, public service agencies need secure broadband capability. Field personnel need to be able to transmit data and images back to the command center and vice versa, the command center needs to provide field personnel with vital information relative to the incident. This needs to be a dynamic exchange of information, rather than a static library of background information which is stored on apparatus laptops.

Problems

In WT Docket 00-32 of the FCC, released on May 2, 2003, 50 MHz of the 4.9 GHz spectrum has been made available for exclusive use by Public Safety Agencies. It is designed specifically for broadband applications.

However – due to the high frequency, the deployment of this spectrum may have problems – including coverage issues because of the line-of-site nature of this frequency band. There are other issues of how to provide coordination between overlapping and adjacent agencies which are all eligible to use the entire spectrum so that interference is mitigated, and interoperability is enhanced. This will require cooperation between the agencies.

Since this frequency has never been deployed before at the authorized power, and since the emissions mask (modulation) is still yet to be determined – it is imperative that pre-deployment testing be done to determine how best to utilize this resource. This grant request is to help pave the way to determine how to best utilize this spectrum for mobile broadband applications in different topographic environments including mountainous, foothills, rural plains, urban, and suburban settings. This will be accomplished through five square mile testing grids. (Appendix C).

There are target fixed access point locations which will utilize existing infrastructure; e.g. power, backhaul options, and antennae. Target locations are West Creek (the east flank of the Hayman Fire), Smokey Hill and Gun Club Road - CFPD, Silver Heights – Castle Rock, Bradbury Tank – Parker, HWY 86 and Ridge Road – IREA, Josephine - Denver Police and Fire Communications Center, I-25 Corridor, Lincoln and Peoria - PFPD Fire Station 74, and Rampart Range and HWY 67 – Devils Head Mountain. In some locations, access will be provided by power or water and sanitation agencies.

One issue includes the type of network hand-offs which will need to be utilized to give persistence (the ability to keep the computers from having to reacquire when they lose the signal). The study will include various options, including mesh-network software which will allow units to both extend coverage into areas which do not have coverage or when coverage is lost and to allow the system to find alternate routes back when existing routes don't work. Another option will be software which allows mobile persistence as units drive in and out of coverage areas. Some of the partner agencies already have access to varying types of this software; others will arrange access for testing purposes with local vendors.

The *Colorado Project* is designed to study, scientifically, how to deploy a high bandwidth broadband mobile system. The bandwidth has been, to this point, unavailable for mobile applications – and is anticipated to be 9 to 12 Mbps minimum. Current applications have considerably lower bandwidth than this, thus limiting video, and other high-band width applications which would greatly enhance the public safety organizations' ability to perform their mission critical operations.

Partners involved in the study are highly qualified engineers and scientists who have the education, skills, and experience to pursue a scientifically sound study. In addition there are committed partners in the public safety field who will participate in the formulation of the study so it will focus on public safety needs and applications.

Innovation

Alternative approaches to acquiring broadband capability have been attempted and rejected. The 900 MHz Broadband applications such as MDS iNet are limited to 512 K of bandwidth and have extreme congestion in this unlicensed band, which makes it difficult to deploy in an urban setting.

Broadband wireless applications are unlicensed with congestions making it difficult to deploy and security issues are a major concern in this band.

The Greenhouse approach uses existing digital trunked radio; however there are bandwidth limitations and lack of availability of sufficient channel capacity. (In major metropolitan areas no new spectrum is available in this frequency range – 800 MHz).

The 4.9GHz Spectrum for public service agency use was formally approved in June 2003 and currently there is no FCC type-accepted equipment for this frequency band; however Proxim will have it available for the "*Colorado Project*." The Office of Engineering and Technology of The FCC was contacted and they expressed the view that it would not be difficult to obtain an experimental license for the project. They stated it should take 30 to 60 days.

Although the FCC is currently granting 4.9 GHz licenses, part of this project is to study one of the proposed emissions mask and see how it performs. Douglas County Sheriff, Denver Communications for Police and Fire, and Cunningham Fire Protection District already have their license and Parker Fire District has a pending application. (Appendix C).

The new frequency range – 4940-4990 GHz offers the following improvements to public service agency communication:

Higher power – although similar products exist in the 5.2 and 5.8 GHz unlicensed band – the power in these bands is different – the new docket authorizes higher power.

New modulation and emissions masks –one of the purposes of this study is to evaluate at least one, and potentially more, possible emissions masks to evaluate their performance.

This frequency range is licensed and regulated and will be issued to public safety entities by jurisdiction. Since the entire bandwidth is given to each jurisdiction, there is an issue of how to deal with overlapping and adjacent jurisdictional use of these frequencies, agreements will need to be put in place with guidelines for interagency cooperation. The FCC has designated this cooperation to local committees. This grant will work with a number of Denver-Area public safety agencies, including the state committee chairman (Emery Reynolds) of the FCC Designated Committee overseeing this spectrum – to determine proposed guidelines for the use of this spectrum in overlapping and adjacent jurisdictional boundaries.

This is an entirely new spectrum with new and emerging technology. Even mobile applications in unlicensed bandwidth are rare, and have considerable problems – this will look at what it takes to deploy this type of network.

Community Involvement

The Spectrum is for Broadband Public Safety Wireless Access, thus the community involvement is limited to the public safety entities which provide emergency response to the community. Historically there has been broad support for improving emergency response capabilities – and in light of the events of 911 – that support is widely recognized. The following agencies have agreed to provide support and/or participation for this project and other utility agencies will provide fixed access point infrastructure where needed:

Partners

The *Colorado Project* partners include Proxim, KNS Communication Consultants, Communications Systems, Inc., Pericle Communications Company, the Douglas County Sheriffs Office, Parker Fire Protection District, Cunningham Fire Protection District and the City and County of Denver. (Appendices B & D)

As a leading manufacturer of wireless broadband products, Proxim will donate in-kind equipment and services for the *Colorado Project* evaluation of the licensed 4.9GHz Spectrum valued at $ 154,992.

KNS Communication Consultants will provide the frequency testing for access point placement and will write the preliminary testing procedures, then work with Pericle Engineering to refine the procedures so they are acceptable to Pericle. KNS Communications will work with the partners to determine the location of the access points, and then do coverage studies of these locations. KNS will perform field testing of the sites, and revise the modeling to reflect actual field test results, compile data, provide preliminary reports for engineering review by Pericle, and provide final reports. KNS will donate $34,346 of in-kind services to the project. KNS will also be available for technical presentations after the completion of the project.

Communications Systems, Inc. (CSI) will provide installation and technical support. This will include installing access points, climbing towers, installing mobile units, repair of equipment if needed. CSI has FCC and PCIA certified technicians on staff, as well as installation personnel. CSI will donate $5,000 of in-kind services to the project.

Pericle Communications Company will provide evaluation services for the *Colorado Project* and will include the use of test equipment as their in-kind contribution. Their rates are equivalent to discounted rental agency rates for the same equipment. Rental agencies usually charge 8%-10% of list price per month. Agencies also rent for a minimum period of one month. They are willing to rent by the week to adapt to your testing schedule and minimize the rental cost over the period of the grant. The value of the in-kind contribution is $20,500. They are also donating $5,600 in engineering services.

Douglas County Sheriffs Office will be the test site for the law enforcement usage of the frequency in the mountainous, foothills, plains, and suburban environments. The northern portions of the suburban environment already have public user interference issues with the unlicensed frequencies. The value of their supplies and services is $16,780.

Parker Fire Protection District will provide the fire and ambulance service testing area for rural, suburban, and E-470 corridor usage. The E-470 corridor presents interference issues and potential interference issues with congested unlicensed frequencies. The in-kind value of PFPDs supplies and services is $32,346. Parker Fire District was awarded a 1997 TIIAP grant for the purposes of developing an interagency broadband network which included video teleconferencing for training and Emergency Operations Center functions. The Douglas County Sheriffs Office was a partner in that project.

Parker Fire replaced the asynchronous T-1 network funded through that project in November 2003 with a wireless 802.11a fixed point system for District facilities.

Cunningham Fire Protection District will provide the suburban, plains, and semi-rural testing area for fire and ambulance personnel in a flat land environment. The value of their services is $1,262.

The City and County of Denver will provide an emergency service environment for an intensely urban environment with the study area to be in the high rise portion of the city as this environment poses a different set of implementation issues. The value of their services is $1,017.

Each partner will provide personnel and vehicles for testing. Each partner will also provide tower space and locations for various access points, as well as mobile data computers for use with testing. (Appendix D)

Sustained Commitment

The *Colorado Project* purpose is to conduct a comprehensive study of the 4.9GHz Spectrum. The answers that come from the test information, will allow the Public Safety Partners, as well as public safety agencies throughout the country, to implement the new Band for agency communications.

Each agency will fund its own 4.9GHz system. If the backwards compatibility is proved, partner agencies will be able to expand their existing systems with reasonable cost. The Douglas County Sheriffs Office is the dispatch center for Parker Fire District and Cunningham Fire District as well as numerous other fire agencies. With this centralized communications center and effective 4.9GHz utilization, migration to the expanded Spectrum will occur quickly. Parker Fire District is already utilizing IP Wireless technology over the 5.8 GHz unlicensed frequency in fixed point applications and is experiencing overlap from general public users. If the 4.9GHz Spectrum is proven effective, Parker Fire intends to implement this frequency District-wide in both fixed and mobile applications.

The City and County of Denver has been searching for a cost effective communication system that would enhance their communication options; particularly in the inner city corridor with the high-rise building interference which is currently affecting their communications.

Project Feasibility

The *Colorado Project* Partner agencies and the state of Colorado are eager to find an effective broadband communication system. The multi-leveled advisory board of this project (Appendix D), coupled with the generous support from Proxim, KNS Communications Consultants (KNS), Pericle Communications Company, and Communication Systems, Inc. (CSI), provide a unique opportunity to enhance public service agency communication capabilities.

The technical approach and implementation plan are described in Appendix A and in the evaluation plan.

Security will be linked to the licensure process as well the normal system security that is in place at each agency and is also addressed in the evaluation criteria.

Organizational Capacity

In view of Parker Fire District's prior experience in multi-agency technical infrastructure development (1997 TIIAP Grant), the organizational capability of the *Colorado Project* is outstanding. The Project Director, Coordinator, and Accountant are the same Parker Fire District personnel that managed the prior project. The staff at the Douglas County Sheriffs Office is also the same individuals that worked on the prior project.

Additionally, all of the Partner Public Service Agencies have highly qualified communications and IT personnel that will be assigned to work on this project.

The technical expertise of Proxim, KNS, CSI, and Pericle along with their in-kind support, provide an outstanding and unusual opportunity to expand the nation's public service agencies' knowledge of the 4.9GHz Spectrum that they so desperately need.

KNS Communications Consultants will provide technical oversight, system design, and testing oversight. KNS will be responsible for preparing reports and technical summaries for the project. Communication Systems, Inc. will provide for the installation equipment in conjunction with some of the various agencies.

Proxim will provide broadband equipment, and will assist with testing and oversight of the installation of access points. Proxim will also donate equipment and engineering time.

Jay Jacobsmeyer of Pericle Engineering will provide independent Professional Engineering review of the project. They will also evaluate suggested test procedures and will assist in providing final test procedures for the project. Final test results will be reviewed for scientific method, accuracy, and results. They will also provide $26,100 in services and testing.

Dissemination

Plans to disseminate lessons learned from the *Colorado Project* include technical data and system design parameters which will be detailed in the final project report and available on CD in adobe format. A web page will detail project progress and studies, presentations to interested parties will be made available, key program staff will present at a minimum of one national seminar, and articles will be written for publication in public safety journals

Evaluation Section

1. Evaluation Strategy. The goal of this project is to demonstrate successful stationary and mobile packet data communications over a 4.9 GHz wireless mesh network in real-world propagation environments to include urban, suburban, rural, flat, foothill, and mountainous. The specific geographic areas to be tested in Denver, Arapahoe, and Douglas counties are described elsewhere in this proposal. Two fundamental figures of merit will be measured:

- Signal strength
- Data throughput

These two figures of merit are related in the sense that an adequate signal strength is required to achieve reliable high speed data, but data throughput is also a function of other channel impairments such as delay spread.

2. Evaluation Questions. Following are the main questions the evaluation seeks to answer:

a. 4.9 GHz Coverage. Wireless data service over 4.9 GHz has not been proven to date. Radio waves at 4.9 GHz encounters severe losses and multipath fading that will hamper performance. What is the coverage radius for 4.9 GHz wireless data coverage under stationary conditions? Mobile conditions? Urban, suburban, rural, flat, foothill, and mountainous environments? Characterize the coverage radius as a function of bit rate for each of these environments and for both stationary and mobile units.

b. Mesh Network Algorithms. A relatively new enhancement to wireless packet data networks (e.g., IEEE 802.11a) is mesh, or *ad hoc* networking. Rather than depend on fixed infrastructure, a mesh network allows both user terminals and access points to act as infrastructure devices. This feature allows the network to adapt its routing paths dynamically. It is especially important for fire protection as firefighting vehicles and mobile command posts must deploy quickly to areas that will in general have no fixed wireless infrastructure. Does the mesh or *ad hoc* routing algorithm work effectively in a real world deployment environment? What penalty in throughput occurs when a user device is also used as an infrastructure device?

c. Handoffs and Seamless Network Operations. Will the network handoff the mobile unit between Access Points without having to reacquire? What are the backhaul requirements for such a network? What are the pros and cons of unlicensed versus licensed wireless backhaul networks? Is this a good application for Mobile IP? What are the pros and cons of Mobile IP?

d. Security and Privacy Issues. It is likely that when 4.9 GHz systems are commercially available (the anticipated release date is December 2004), they will be backward compatible with IEEE 802.11 systems, specifically IEEE 802.11a. This backward compatibility is desirable because public safety will benefit from the economies of scale offered by commercial packet radio systems. However, public safety has some important security and privacy requirements that may not be met automatically by IEEE 802.11-based networks. The questions to be answered include:

Access to Network - Is there a robust authentication method? If 802.11a is used, the evaluators have considerable experience with its security shortfalls through their work with U.S. airports.

Protection of confidential information – WEP or AES encryption? How often are keys changed? Can VPN networks be established through the network?

Protocols and standards to control security - Are elements of new security standard, IEEE 802.11i, implemented? Is the equipment compatible with Virtual Private Network (VPN), an industry-standard end-to-end encryption method? Does the particular deployment architecture and mesh algorithm pose problems for secure end-to-end connections? What happens to the secure connection when the unit hands off or re-connects with a different AP?

4) Security within radio - If the radio is lost or stolen, can the system be programmed to deny access? Is there are tamper-proof ID (MAC address) in the radio to prevent identify theft?

e. Technology Issues. There are some technology issues that must be addressed:
Equipment evaluation - Does the equipment work as advertised? Is it appropriate for this application and deployment environment? I.e. is it rugged enough for mobile deployments? What improvements would be needed for an operational system?

Emissions Mask Issues – The current FCC emissions mask is not compatible with IEEE 802.11a. This is an issue raised to the FCC, but not yet decided. Discuss the impacts of an incompatible emissions mask, compare FCC mask to 802.11a mask, etc.

3. Data Collection and Analysis Plan. The main elements of the test plan are as follows:

a. Using radio propagation software (Softwright **TAP**) and digital terrain elevation data, prepare coverage maps for several sets of AP locations. Note that we expect to install 20 access points in Denver and along the E470, I-25, Highway 67 corridors.

b. After conducting the computer-aided study above, install two or three APs and drive test the expected coverage area. Compare the drive test measurements to the predictions. Do the predictions accurately represent real-world coverage?

c. Adjust the AP locations based on the drive test measurements to attempt to get seamless coverage.

d. Drive test the downtown Denver urban area and highway corridors. Collect measurements to assess signal strength, throughput, and mesh algorithm performance.

The principal measurement instrument is an Agilent E4405B Spectrum Analyzer which operates from 9 kHz to 13 GHz. The spectrum analyzer is software controlled, allowing automatic data collection while driving. The software controller resides on a laptop computer and also controls an external GPS receiver. Thus, each measurement will have a time stamp and geographic coordinates, allowing automatic plotting on digital maps or overhead digital photographs.

The secondary measurement instrument is an IEEE 802.11a wireless LAN card with external antenna and 4.9 GHz radio interface. The wireless LAN card receives and decodes data broadcast from the tower-top 4.9 GHz access points. The wireless LAN card will be controlled by a commercial software program, **AiroPeek**, by Wildpackets, Inc. Airopeek monitors traffic through the card and records MAC address of each AP, throughput, packet-error rate, and other performance statistics.

Because signal level and throughput will be measured simultaneously and will appear in the same record, one can plot throughput versus signal strength to determine what minimum signal level is required under stationary and mobile conditions to achieve maximum throughput. Also, if signal strength and throughput are not strongly correlated, one can deduce that other channel impairments, such as delay spread, are hampering throughput.

Network backhaul information will also be collected simultaneously with the drive test measurements to verify that packets are routed successfully from AP to AP and from user device to user device using the mesh algorithm.

4. Final Evaluation Report. Pericle Communications Company will prepare a final report providing the test results and implementation criteria.

5. Evaluators. The evaluation will be conducted by Pericle Communications Company, an independent consulting engineering firm specializing in wireless communications. A description of the company with resumes is attached in Appendix B.